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Procedia Engineering 150 (2016) 1287 – 1290

**Procedia  
Engineering**[www.elsevier.com/locate/procedia](http://www.elsevier.com/locate/procedia)

International Conference on Industrial Engineering, ICIE 2016

# Characteristics of the Diesel 4CHN13/15 Working Process with Exhaust Gases Recirculation and their Cooling in the Vortex Tube

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## Abstract

The article outlines the results of comparative assessment of characteristics of the diesel 4ChN13/15 working process with exhaust gases recirculation and their cooling in the vortex tube. It is shown that the presence of cooling on the most exploited mode of work of the engine ( $n=1250 \text{ min}^{-1}$ , loading 75 %), with the share of recycled gases in the fresh charge equal to 18% and their cooling on 60K, gives an observable temperature difference of the fresh charge on the input to cylinder, the maximum and average gases temperature in the head-end volume. Moreover, a lower fresh charge temperature in case of cooling the recycled gases provides the increase of oxygen mass fraction in the head-end space, and, consequently, it allows boosting the fuel combustion which leads to a more intensive heat generation.

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Peer-review under responsibility of the organizing committee of ICIE 2016

*Keywords:* Diesel; exhaust gases; noxious substances; recycled gases; vortex tube; temperature.

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## 1. Introduction

The article [1,2] displays, that to provide the diesel correspondence to current and promising standards concerning the toxicity, it is necessary to use methods of reduction hazardous air pollutants (HAPs), including the mixture of recycled exhaust gases system (EG) with cooling of recirculated gases (RG) [3-20] and neutralization of EG [6-11]. Nonetheless, it was shown that to cool recirculated gases it is rational to use vortex tube [12-16].

The article also outlines the results of experimental assessment of VT usage for efficiency upgrading of EG recycling on diesel 4CHN13/15.

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## 2. Experiment

Test object – diesel 4ChN13/15 – four - stroke diesel with the direct fuel injector, liquid cooling and gas turbine charging, equipped with EG recycling and neutralization systems in different variations and packages. Diesel testing was conducted on testing bench «Certification centre of automotive engineering» (Chelyabinsk), certified in stated order. Fig. 1 depicts fragments of experimental facility with elements of system of recycled EG.

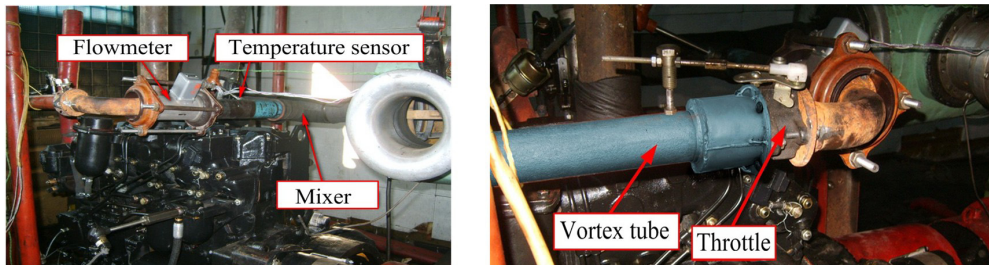


Fig. 1. (a) flowmeter installation, temperature sensor of recycled gases and mixer; (b) installation of vortex tube and throttle, controlling the volume of recycled gases.

EG recycled system with VT provided the ability to control the volume flow rate of RG in range not less than 0-20% from volume flow rate of fresh charge and finite cool down of RG for 60K concerning the EG temperature, penetrating VT.

Data processing was conducted in accordance with GOST(All Union State Standard) 18509-88 and GOST P 41.96-2011 and GOST 17.2.2.02 .

## 3. Results

The major part of obtained material, demonstrating characteristics of working process of diesel 4ChN13/15 with recycled EG and their cooling demands more space to show all the results. Consequently the following comparing data according to the influence of RG cooling for their share in fresh charge, equal to 18%, conditional upon their temperature fall till 60K.

It is known that the emission index of solid particles is twice higher than nitrogen oxides, 10 times than hydrocarbons, and 20 times than carbon oxides. [2,17,18]. Accordingly during the analysis of diesel functioning with EG recirculation we were restricted by 2 working modes, where maximum emission of solid particles and nitrogen oxides take place. These modes for diesels with extensional carburetion (the investigated diesel falls into this diesel group) are supposed to be loaded in the range from 62,5 to 87,5 % [3,19,20]. That's why the following information is received on the supreme rolling moment ( $n=1250 \text{ min}^{-1}$ ) and loading of 75%. Fig. 2 Illustrates temperature variations of working medium on the reported mode without cooling RG and with cooled RG.

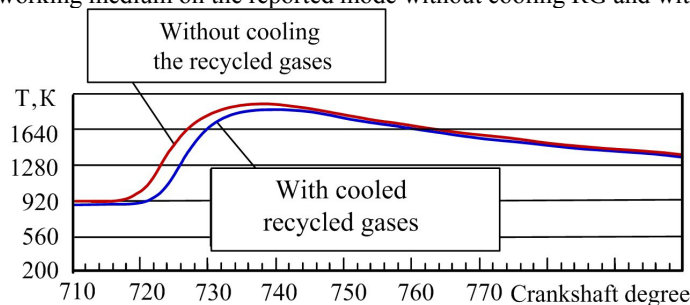


Fig. 2 Illustrates temperature variations of working medium on the reported mode without cooling RG and with cooled RG.

The picture reveals the certain difference of gas thermal condition in combustion chamber in both cases. In particular, calculations discovered that the temperature difference of the fresh charge on the entrance to the cylinder in case of cooling RG in VT and without it, is equal to 11K, the maximum temperature point of gases in head-end volume without cooling was 1885K, in case of cooling - 1819K. The average temperature of the working medium in the depicted range on crankshaft degree in the first case was equal to 1571 K, in the second - 1513 K.

The lower temperature of 1513 K fresh charge with cooling RG provided elevation of its solidity and consequently an increase of oxygen mass content in head-end space approximately on 30% (fig.3).

It leads to faster combustion of fuel vapour, generated during the ignition lag, correspondingly to more intensive heat emission. The speed of heat emission with cooling RG during short period of time increases rapidly and reaching the certain maximum (approximately 40J/ Crankshaft degree), also decreased in the same tempo (fig. 4).

Without cooling RG the maximum speed of heat emission was equal only to 13 J/Crankshaft degree. Obviously, during this period of time kinetic combustion mechanism prevailed.

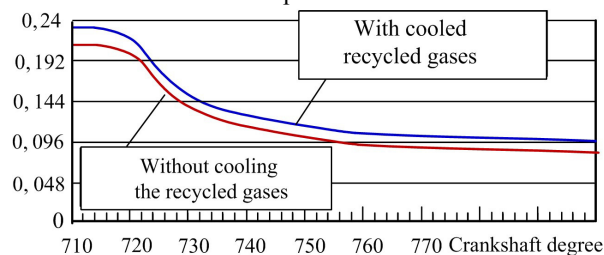


Fig. 3 Variations of oxygen mass content in head-end space without cooling RG and with cooled RG

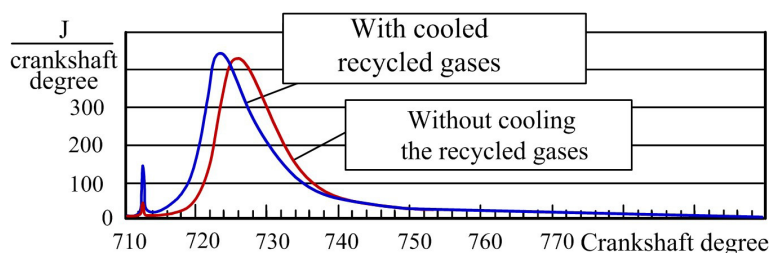


Fig. 4 The speed of heat emission in head-end space without cooling RG and with cooled RG

The content of great amount of acidifier in combustion chamber with cooling RG also provided an earlier fuel burning in diffusion phase, which is depicted in diagrams Fig. 5 and 6.

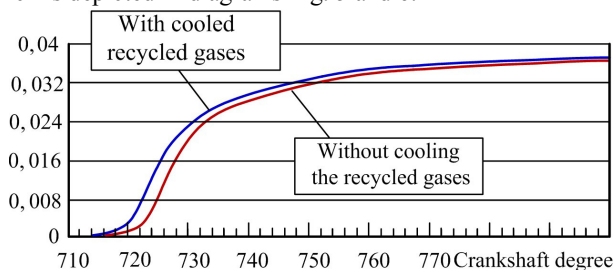


Fig. 5. Alteration of mass fraction of burn up fuel in head-end space without cooled RG and with cooling RG

The investigated behavior characteristics of combustion process with cooling RG led to more complete heat emission (fig 6.), with an impact on fuel flow density decreasing, recorded during the experiment.

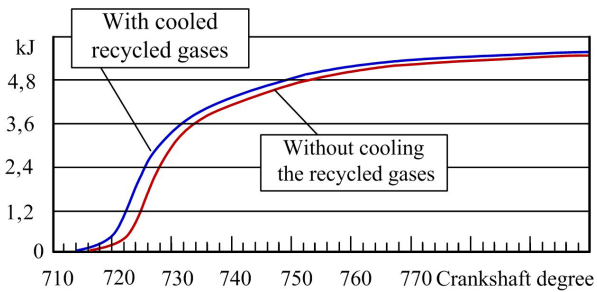


Fig. 6. Integral characteristics of heat emission in head-end volume without cooled RG and with cooling RG.

On the mode typical of agricultural and road-building cars, which is the diesel 4ChN13/15 ( $n=1250 \text{ min}^{-1}$ , loading 75 %), with share of RG in fresh charge 18%:

- Cooling of RG for 60K provided visible temperature difference of fresh charge on the entrance to the cylinder – 11K in comparison without cooled RG. The maximum gas temperature in head-end volume without cooling is equal to 1885K, with cooled - 1819K. The average temperature of working medium in range from 710 to 800 Crankshaft degrees, in first case was 1571K, in the second – 1513K.
- The lower fresh charge temperature with cooling RG provides the amelioration of oxygen mass fractioning head-end space approximately on 30% (with cooling RG on 60K), faster fuel burning and consequently more complete heat emission.

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